

# **BROADBAND INVERSION IN SHALLOW WATER**

Michael B. Porter

Center for Communications and Signal Processing Research

New Jersey Institute of Technology, Newark, NJ 07102

phone: (619) 534-7514 fax: (619) 534-7514 email: porter@oalib.njit.edu

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Shallow Water Acoustics

## **LONG-TERM GOAL**

Largely as a result of the exponential growth in computer technology, we can now embed sophisticated acoustic models in SONAR and ocean-observing systems. We seek to do so in a physics-based sense, with an understanding of what acoustic features can *reliably* be exploited in the signal-processing algorithms.

## **SCIENTIFIC OBJECTIVES**

The specific objectives are to study acoustic propagation in topographically and oceanographically complex areas; to identify robust features in the channel response; and thereby to design robust signal-processing algorithms to both track quiet sources and observe the marine environment.

## **APPROACH**

The experimental component is central to this effort. In the last year I participated as a partner in the tri-national (France-Portugal-US) INTIMATE 96 experiment (Internal Tide Monitoring by Acoustic Tomography Experiment). I am also collaborating with NUWC on the MLTA program and will be involved in the processing of data from the December 1997 Key West experiment.

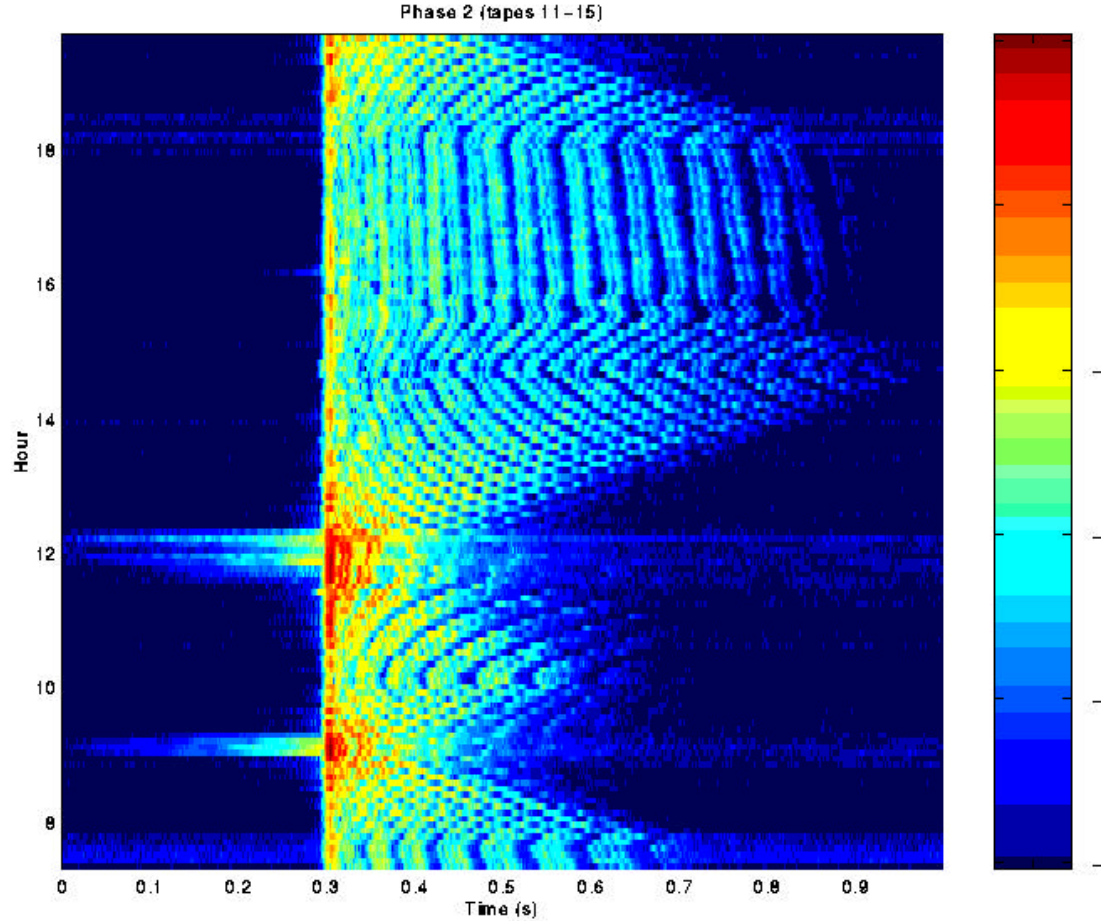
## **WORK COMPLETED**

Data from INTIMATE 96 was processed shortly after the June 1996 experiment to yield correlograms for I) a 25 hour station with a cross-slope acoustic path, II) a 14 hour track where the source was towed over a series of radials in both cross-slope and down-slope directions, III) a 25 hour station with an up-slope acoustic path. In the last year, we have completed extensive studies on both the forward modeling and inversion. The 3D effects due to the shelf-break topography, and the temporal effects due to the tides were studied in depth. Inversion has been applied to both the source position and the oceanographic structure of the channel and compared to independent measurements (GPS, ADCP, CTD).

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## RESULTS

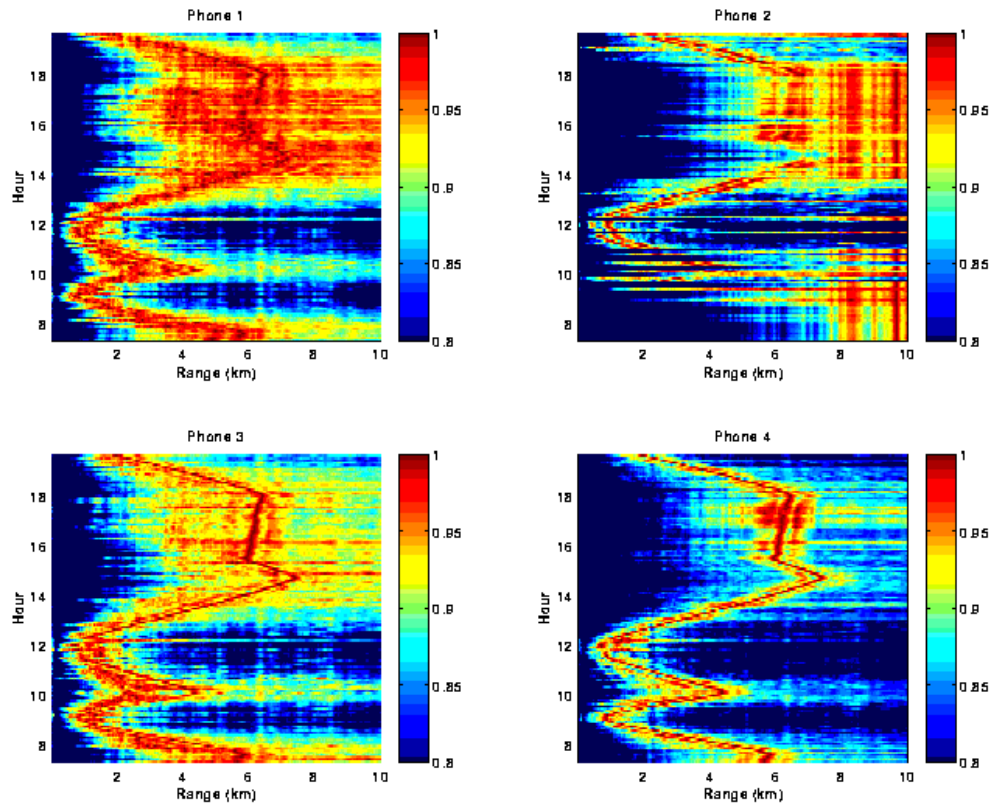
Figure 1 shows the resulting pattern of echoes received over a 14 hour period during which the source ship transmitted chirps every 8 seconds. When the source is at long ranges we see a correspondingly long echo response involving some 20 surface and bottom reflections. The echo response is stable during the period between 14:30 and 18:00 when the source traversed an arc at constant radius.



*Figure 1: Correlograms showing ocean-channel echo response as the source is towed around the array.*

With this information, we are able to identify precisely the sources of model error (bottom-type, ocean structure, experiment geometry etc.). We found that the model/data correlation was primarily dominated by an early arriving cluster of unresolvable RBR (refracted/bottom-reflected) paths.

The signal-processing algorithm was modified by a logarithmic transform enabling us to track the source using a simple flat-bottom model and a single snapshot of the sound speed profile. This was done using each of the 4 phones in the vertical array as shown in Figure 2. Surprisingly the processing is so robust that we are even able to track the source using 'dead' phone 2 (upper right-hand corner) which had become flooded with salt-water.



*Figure 2: Source range derived from each of the 4 phones in the array.*

## IMPACT/APPLICATION

The INTIMATE 96 data suggests that shallow-water environments may be much more predictable than had widely been thought. The broadband studies performed here, make clear the source of the variation and have allowed us to implement a robust approach to source tracking which we hope will have a significant impact on naval SONAR systems. Similarly, the insights about the effects of barotropic and baroclinic oceanographic modes should lead to improved tomographic imaging systems.

## TRANSITIONS

We are currently laying plans for INTIMATE 98 which will cover explore both a larger scale and a new site (Gulf of Gascogne). In addition, I am currently working with NUWC on the multi-line towed array system and we hope to transition the resulting algorithms to an operational system

## RELATED PROJECTS

INTIMATE is linked to the PRECOCE (PREdiction du comportement des Couches superficielles de l'Océan le long des Côtes Européennes) project which is designed to develop enhanced upper ocean models for European coastal areas. As mentioned above, the signal processing work is also linked to the NUWC/MLTA program.

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